Mission: To Advance Knowledge and Understanding of the Atmospheres of the Earth and Other Planets

1. INTRODUCTION

How can we improve our ability to predict the weather-tomorrow, next week, and into the future?

How is the Earth's climate changing? What causes such change? And what are its costs?

What can the atmospheres of distant planets teach us about our own planet and its evolution?

The Laboratory for Atmospheres is helping to answer these and other scientific questions about our planet and its neighbors. The Laboratory conducts a broad theoretical and experimental research program studying all aspects of the atmospheres of the Earth and other planets, including their structural, dynamical, radiative, and chemical properties, with the overarching goal to provide better understanding and to improve prediction of the Earth's climate.

Vigorous research is central to NASA's exploration of the frontiers of knowledge. NASA scientists play a key role in conceiving new space missions, providing mission requirements, and carrying out research to explore the behavior of planetary systems, including, notably, the Earth's. Our Laboratory's scientists also supply outside scientists with technical assistance and scientific data to further investigations not immediately addressed by NASA itself. Laboratory scientists submit competitive research proposals with diverse scientific or technological approaches to NASA and other Federal agencies to acquire research support. The Laboratory management strives to provide a working environment that promotes creativity, competition, and openness.

The Laboratory for Atmospheres is a vital participant in NASA's research program. Our Laboratory often has relatively large programs, sizable satellite missions, or observational campaigns that require the cooperative and collaborative efforts of many scientists. We ensure an appropriate balance between our scientists' responsibility for these large collaborative projects and their need for an active individual research agenda. This balance allows members of the Laboratory to continuously improve their scientific credentials.

The Laboratory places high importance on promoting and measuring quality in its scientific research. We strive to assure high quality through peer-review funding processes that support approximately 90% of the work in the Laboratory. The overall quality of our scientific efforts is evaluated periodically by committees of advisors from the external scientific community, as detailed in Appendix 2 of this document.

Members of the Laboratory interact with the general public to support a wide range of interests in the atmospheric sciences. Among other activities, the Laboratory raises the public's awareness of atmospheric science by presenting public lectures and demonstrations, by making scientific data available to wide audiences, by teaching, and by mentoring students and teachers. Section 6 presents details of the Laboratory's outreach activities during 2002. The Laboratory is also committed to addressing the demographic imbalances that exist today in the atmospheric and space sciences. We must address these imbalances for our field to enjoy the full benefit of all of the Nation's talent. The Laboratory makes substantial efforts to attract new scientists to the fields of atmospheric and space sciences. We strongly encourage the establishment of partnerships with Federal and state agencies that have operational responsibilities to promote the societal application of Earth sciences.

The Laboratory is part of the Earth Sciences Directorate (Code 900) based at NASA's Goddard Space Flight Center in Greenbelt, Maryland. The Directorate itself is comprised of the Global Change Data Center (902); the Earth and Space Data Computing Division (930); three laboratories–the Laboratory for Atmospheres (910), the Laboratory for Terrestrial Physics (920), and the Laboratory for Hydrospheric Processes (970); and the Goddard Institute for Space Studies (GISS) in New York, New York.

In this report, you'll find a description of our role in NASA's mission. You'll also find a broad description of our research and a summary of our scientists' major accomplishments in 2002. The report also presents useful information on human resources, scientific interactions, and outreach activities with the outside community.

For your convenience, we have published a version of this report on the Internet. Our Web site includes links to additional information about the Laboratory's Offices and Branches. You can find us at http://atmospheres.gsfc.nasa.gov/

2 STAFF, ORGANIZATION, AND FACILITIES

Staff

The diverse staff of the Laboratory for Atmospheres is made up of scientists, engineers, technicians, administrative assistants, and resource analysts. The total head count is about 415, including civil servants, associates, and contractors. The civil servant composition of the Laboratory consists of 86 “in-house” members and 13 co-located members (5 resource analysts, 1 scientist, 3 engineers and 4 technicians). Of the 86 in-house civil servants, 78 are scientists, 4 are engineers. Out of the 82 civil servant scientists and engineers, 74 (or 90%) hold doctor’s degrees, 3 hold master’s degrees, and 5 hold bachelor’s degrees. These 74 people constitute 86% of the total workforce as indicated in Figure 1.

An integral part of the Laboratory staff is composed of onsite research associates and contractors. The research associates are primarily members of joint centers between the Earth Sciences Directorate and nearby universities (JCET, GEST, and ESSIC), or are employed by universities with which the Laboratory has a collaborative relationship such as George Mason University, University of Arizona, and Georgia Tech. Out of the 92 research associates, 82 or 89% hold Ph.D.s. The onsite contractors are a very important component of the staffing of the Laboratory. Out of the total of 223 onsite contractors, 60 or 27% hold Ph.D.s.

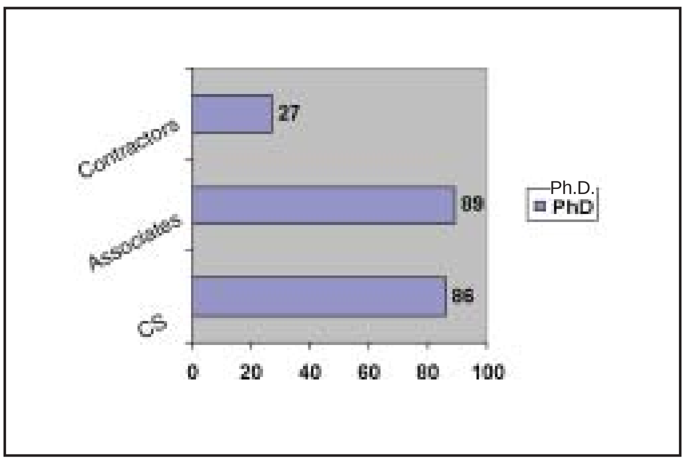

Figure 1. Percentage of Ph.D.s among Civil Servants, Associates, and Contractors in the Laboratory for Atmospheres.

A measure of the productivity of the Laboratory members and of their extensive collaboration with outside scientists is shown in the following chart, Figure 2. The extensive and increasing collaboration is borne out by the large numbers of papers having both first author and coauthor from outside our Laboratory.

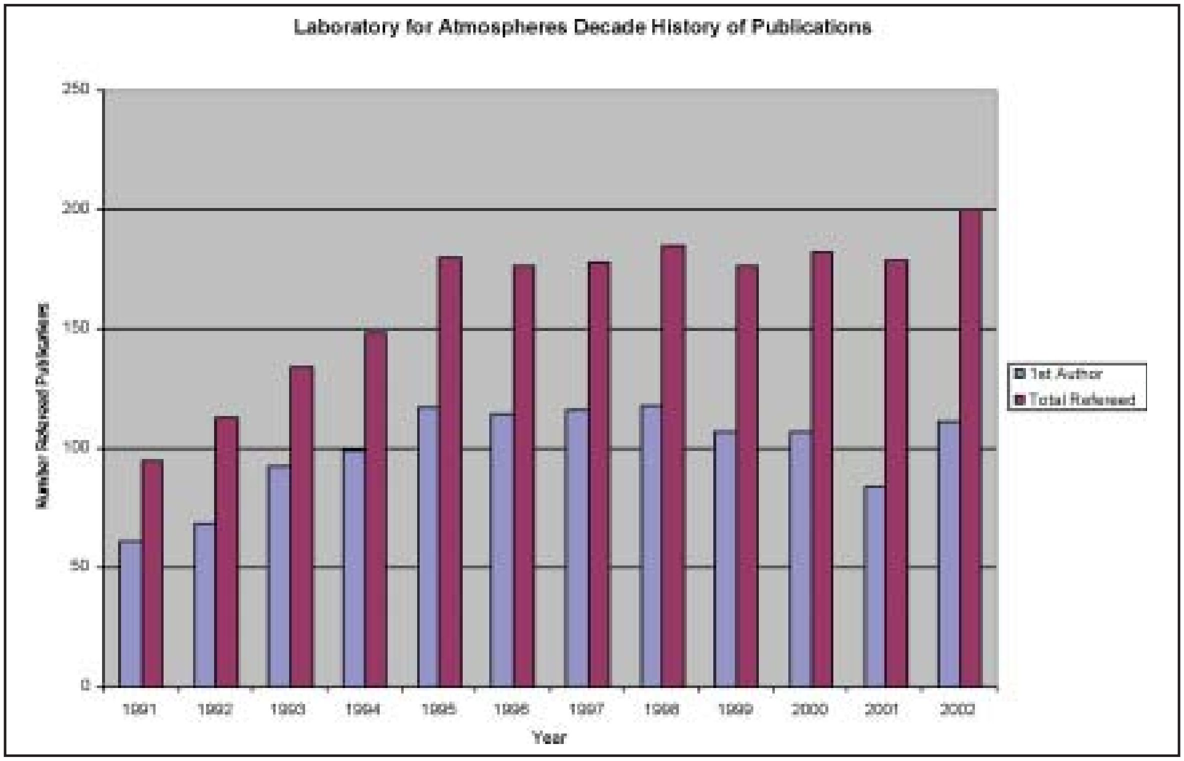

Figure 2. Chart of number of refereed publications by Laboratory for Atmospheres members over the years. Red bar is the total number of publications where a Laboratory member is a 1st author or coauthor of the paper, and the blue bar is the number of publications where a Laboratory member is 1st author. The chart exhibits a trend over time for increased collaboration, where Laboratory members are coauthors on papers written by outside scientists.

Organization

Figure 3 shows the Laboratory management structure.

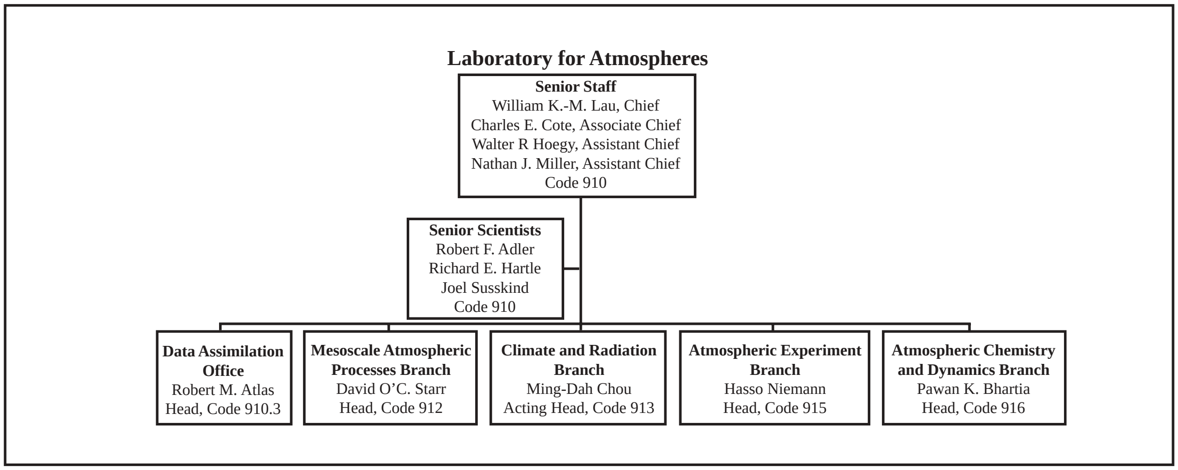

Figure 3. Laboratory for Atmospheres Organization Chart.

Branch Descriptions

The Laboratory has traditionally been organized into branches even though we work on science projects which are becoming more and more of a crosscutting nature. The organization chart exhibits our present branch organization. Branch members collaborate with each other within their branch, across branches, and across Divisions within the Directorate. Some of the recent crosscutting areas of research of interest to the Laboratory (and which are also science drivers of the Directorate) are: Global Water and Energy Cycle, Carbon Cycle, Weather and Short-Term Climate Forecasting, Long-Term Climate Change, Atmospheric Chemistry, Aerosols, and Planetary Studies. The composition of the Senior Staff Office (910) and the 5 branches is broken down by Civil Servants, Associates, and Contractors in Figure 4.

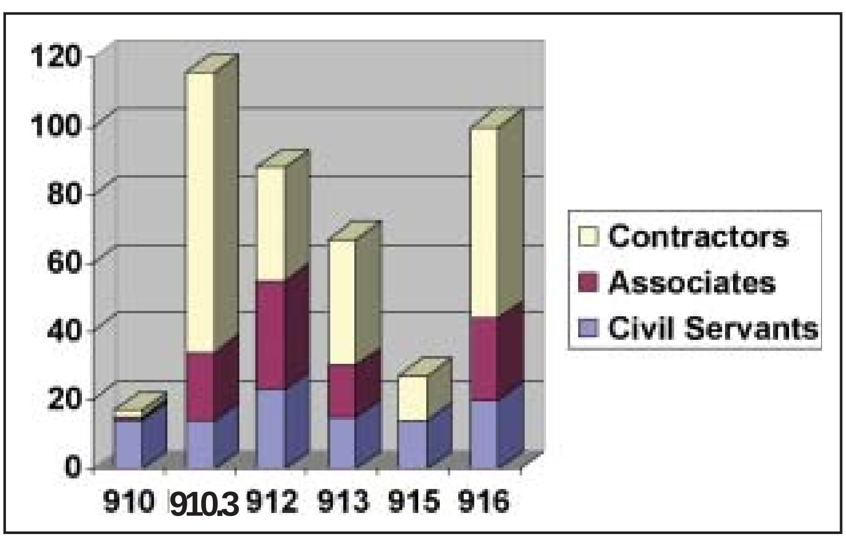

Figure 4. Employment composition of the members of the Laboratory for Atmospheres.

A brief description is given for each of the Laboratory's five Branches. In Section 5, the Branch Heads summarize the science goals and achievements of their branches, followed by science highlights.

Data Assimilation Office (DAO), Code 910.3

The DAO combines all available meteorologically relevant observations with a prognostic model to produce accurate time-series estimates of the complete global atmosphere. The DAO performs the following functions:

- Advancing the state of the art of data assimilation and the use of data in a wide variety of Earth-system problems
- Developing global data sets that are physically and dynamically consistent
- Providing operational support for NASA field missions and space shuttle science
- Providing model-assimilated data sets for the Earth Science Enterprise

For additional information on DAO activities, consult the Web (http://dao.gsfc.nasa.gov/).

Mesoscale Atmospheric Processes Branch, Code 912

The Mesoscale Atmospheric Processes Branch studies the physics and dynamics of atmospheric processes, using satellite, aircraft, and surface-based remote-sensing observations as well as computer-based simulations. This Branch develops advanced remote-sensing instrumentation (with an emphasis on lidar) and techniques to measure meteorological conditions in the troposphere. Key areas of investigation are cloud and precipitation systems and their environments–from individual cloud systems, fronts, and cyclones, to regional and global climate. You can find out more about Branch activities on the Web (http://rsd.gsfc.nasa.gov/912/code912/).

Climate and Radiation Branch, Code 913

The Climate and Radiation Branch conducts basic and applied research with the goal of improving our understanding of regional and global climate. This group focuses on the radiative and dynamical processes that lead to the formation of clouds and precipitation and on the effects of these processes on the water and energy cycles of the Earth. Currently, the major research thrusts of the Branch are climate diagnostics, remote-sensing applications, hydrologic processes and radiation, aerosol/climate interactions, seasonal-to-interannual variability of climate, and biospheric processes related to the carbon cycle. You can learn more about Branch activities on the Web (http://climate.gsfc.nasa.gov/).

Atmospheric Experiment Branch, Code 915

The Atmospheric Experiment Branch carries out experimental investigations to further our understanding of the formation and evolution of various solar system objects such as planets, their satellites, and comets. Investigations address the composition and structure of planetary atmospheres, and the physical phenomena occurring in the Earth's upper atmosphere. We have developed and are constantly refining neutral gas, ion, and gas chromatograph mass spectrometers to measure atmospheric gas composition using entry probes and orbiting satellites. You can find further information on Branch activities on the Web (http://webserver.gsfc.nasa.gov/).

Atmospheric Chemistry and Dynamics Branch, Code 916

The Atmospheric Chemistry and Dynamics Branch engages in four major activities:

- Developing remote-sensing techniques to measure ozone and other atmospheric trace constituents important for atmospheric chemistry, climate studies, and air quality
- Developing models for use in the analysis of observations
- Incorporating results of analysis to improve the predictive capabilities of models
- Providing predictions of the impact of trace gas emissions on our planet's ozone layer

For further information on Branch activities, consult the Web (http://hyperion.gsfc.nasa.gov/).

Facilities

Computing Capabilities

Computing capabilities used by the Laboratory range from high-performance supercomputers to scientific workstations to desktop personal computers.

The high-performance computers are operated for general use by the NASA Center for Computational Sciences (NCCS). Their flagship machines are a Compaq Alpha Server SC45 with 1392 (512 1 GHz and 880 1.25 GHz) Alpha-EV68 processors and 696 GB of main memory, an SGI Origin 3800 with 512 400 MHz CPUs and 256 GB of main memory, and an SGI Origin 3800 with 128 500 MHz CPUs and 64 GB of main memory. The NCCS provides a mass storage system with a potential capacity of over 10 PB. Supercomputer resources are also available through special arrangement from NASA Ames Research Center, NASA Advanced Supercomputing (NAS) facility.

Each Branch maintains its own system of computers. With the availability of very fast, large capacity, relatively inexpensive personal computers, the trend for Laboratory scientists is away from clusters of Unix workstations and toward using personal computers as scientific workstations. The major portion of scientific data analysis/manipulation and image viewing is done on the single user personal computers.

GOES Receive Site

The Laboratory operates an autonomous ground station for continuously receiving, processing, and serving the Imager and Sounder radiometric data from the GOES satellites. The site also offers recent international geosynchronous satellite data from Japan (GMS-5), China (FY-2), and Europe (METEOSAT-5 and -7). In addition, we offer a database of full-resolution radiances from India's geosynchronous satellite (INSAT) which began in March 1999.

Mass Spectrometry

The Laboratory for Atmospheres' Mass Spectrometry Laboratory is equipped with unique facilities for designing, fabricating, assembling, calibrating, and testing flight-qualified mass spectrometers used for atmospheric sampling.

The equipment includes precision tools and machining, material processing equipment, and calibration systems capable of simulating planetary atmospheres. The facility has been used to develop instruments for exploring the atmospheres of Venus, Saturn, and Mars (on orbiting spacecraft), and of Jupiter and Titan (on probes). The Mass

Spectrometry Laboratory will also be used in support of comet missions. In addition, the Laboratory has clean rooms for flight instrument assembly and equipment for handling poisonous and explosive gases.

Lidar

The Laboratory has well-equipped facilities to develop lidar systems for airborne and ground-based measurements of aerosols, methane, ozone, water vapor, pressure, temperature, and winds.

Lasers capable of generating radiation from 266 nanometer (nm) to beyond 1,000 nm are available, as is a range of sensitive photon detectors for use throughout this wavelength region. The lidar systems employ telescopes with primaries up to 30 inches in diameter and high-speed counting systems for obtaining high vertical resolution. The Cloud, Aerosol, Lidar, Radiometer Laboratory has specialized facilities for optical instrument development, including optical tables, large auto-collimator, air handlers, and flow bench.

Lidars developed in the Laboratory include the Airborne Raman Ozone, Temperature, and Aerosol Lidar (AROTAL) to measure ozone, temperature, and aerosols; the Stratosphere Ozone Lidar Trailer Experiment (STROZ LITE) to measure atmospheric ozone, temperature, and aerosols; the Aerosol and Temperature Lidar (AT Lidar) for measurement of stratospheric temperature and aerosols, and tropospheric water vapor; the Large Aperture Scanning Airborne Lidar (LASAL) to measure clouds and aerosols; the Cloud Physics Lidar (CPL) to measure clouds and aerosols; the Scanning Raman Lidar (SRL) to measure water vapor, aerosols, and cloud water; and the Goddard Lidar Observatory for Winds (GLOW) which uses an edge technique to measure winds. A Cloud and Aerosol Lidar, the Aerosol Lidar (AL) is currently being built for deployment to Kritimati Island (Christmas Island).

The Code 912 Raman Lidar Laboratory has instrumentation for performing a broad range of atmospheric measurements using backscatter, polarization and Raman lidar techniques. Recent activities in the Lab include multiwavelength lidar measurements for studying aerosol and cloud properties, spectrally scanned measurements of Raman scattering from atmospheric CO_2, O_2, N_2, water vapor and liquid water. In addition, the Raman Airborne Spectroscopic Lidar (RASL), recently developed under the Instrument Incubator Program, has completed successful testing in the Raman Lidar Laboratory and is currently being configured for first flight. RASL offers daytime and nighttime measurements of water vapor mixing ratio, aerosol backscattering, aerosol extinction and aerosol depolarization as well as nighttime measurements of cloud liquid water.

The next generation Micro-Pulse Lidar (MPL) design was recently prototyped in our Laboratory, and is undergoing transfer to a company to become a commercial product. The next generation MPL includes more rugged components for better durability in the field, a longer lasting laser system, a fiber coupled detector arrangement for in-the-field repair, a multichannel data system to include measurement of the lidar overlap function in real-time, and computer control of all the MPL components via an internet connection.

Members of the Laboratory are building a new lidar calibration facility called SLAM (Small Lidar Advanced Measurement). It will be used primarily to calibrate and maintain the several MPL systems here at Goddard, and other privately owned MPL systems that are part of our MPLNET project. It can also be used to calibrate other small optics.

Radiometric Calibration and Development Facility

The Radiometric Calibration and Development Facility (RCDF) supports the calibration and development of instruments for ground- and space-based observations of atmospheric composition including gases and aerosols. http://ventus.gsfc.nasa.gov

As part of the Earth Observing System (EOS) calibration program, the RCDF provided and will provide calibrations for all UV/VIS spaceborne solar backscatter instruments, which include Solar Backscatter Ultraviolet/ version 2 (SBUV/2), and Total Ozone Mapping Spectrometer (TOMS) instruments. Calibrations were conducted on the Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY), flying on European Space Agency's (ESA) Environmental Satellite (ENVISAT) mission, ODIN Spectrometer and IR Imager System (OSIRIS), on the Canada/Sweden ODIN mission, and the Israeli MEIDEX (Mediterranean Israeli Dust Experiment) and SOLSE/LORE shuttle instruments. Calibrations are scheduled for the Ozone Monitoring Instrument on Aura and the Global Ozone Monitoring Experiment-2 (GOME-2) on Metop.

The RCDF also supports Instrument Incubator Program development such as the Compact Hyperspectral Mapper for Environmental Remote Sensing Applications (CHyMERA) and the Geostationary Spectrometer (GeoSpec). The Shuttle Ozone Limb Sounding Experiment/Limb Ozone Retrieval Experiment (SOLSE/LORE) were also developed in the RCDF.

The RDCF also houses several instruments for conducting zenith sky observations. The SSBUV instrument that flew on the space shuttle eight times during the period 1989 to 1996 is now routinely collecting zenith sky observations as part of a Code 916 program called *Skyrad*. The objective of this program is to improve radiative transfer models and algorithms used for UV/VIS space- and ground-based backscatter instruments. The RDCF also maintains a double Brewer spectrometer, used as field calibration transfer, and several other sky-observing instruments for composition and aerosol research. Experiments are being conducted to determine if calibrated zenith sky observations can be used to validate radiance observed from space. This technique could be applicable to present fly UV/VIS backscatter instruments and future operational instruments on NPP, NPOESS and Metop.

The RCDF contains state-of-the-art calibration equipment and standards traceable to the National Institutes of Standards and Technology (NIST). Calibration capabilities include wavelength, linearity, signal to noise (s/n), instantaneous field of view (IFOV), field of regard (FOR), and goniometry. The facility is also capable of characterizing such instrument subsystems as spectral dispersers and detectors. A tunable dye laser operating in the UV/VIS is also used to measure optical filter characteristics with high accuracy and to characterize instrument throughput such as slit functions and wavelength registration. The Facility includes a class-10,000 clean room with a continuous source of N_2 for added contamination control. For further information contact Ernest Hilsenrath (hilsen@ventus.gsfc.nasa.gov).

3. OUR WORK AND ITS PLACE IN NASA'S MISSION

NASA's Enterprises

NASA's overall program, as outlined in the Agency's strategic plan, is composed of five enterprises: Earth Science; Space Science; Aerospace Technology; Biological and Physical Research; and Human Exploration and Development of Space. The Laboratory for Atmospheres concentrates on two of these, the Earth Science and Space Science Enterprises.

Earth Sciences Directorate Areas of Research

The Earth Sciences Directorate research is driven by a number of crosscutting science areas on which the Laboratory for Atmospheres focuses much of its research:

- Aerosols
- Atmospheric Chemistry
- Carbon Cycle
- Global Water and Energy Cycle
- Long-Term Climate Change
- Planetary Studies
- Weather and Short-Term Climate Forecasting

Earth Science and Space Science in the Laboratory for Atmospheres

The Laboratory for Atmospheres has a long history (40+ years) of research in Atmospheric Science, both of the Earth and the planets. The wide array of our work reflects this history of atmospheric research, from the early days of weather satellites and emphasis on weather forecasting to a present focus on global climate change. For example, one goal is to increase the accuracy and lead-time with which we can predict weather and climate change. Our history also reflects research from the early days of the OGO (Orbiting Geophysical Observatory), Explorer, and Pioneer Venus Satellites to Galileo missions, and current studies of the outer planets and comets with the Mars Nozomi mission, the Cassini mission to measure the chemical composition of gases and aerosols in the atmosphere of Titan, and the Ion and Neutral Mass Spectrometer (INMS) to measure the chemical composition of positive and negative ions and neutral species in the inner magnetosphere of Saturn and in the vicinity of Saturn's icy satellites.

The Laboratory for Atmospheres conducts basic and applied research in the crosscutting research areas of the Earth Sciences Directorate. Specifically, Laboratory scientists focus their efforts on satellite mission planning, data development and analysis, data assimilation and modeling in the following areas:

- Aerosols and clouds
- Atmospheric hydrological processes
- Atmospheric radiative transfer
- Carbon sources and sinks
- Climate variability and forcings
- Composition of planetary atmospheres
- El Niño and predictability studies
- Observing system simulation studies
- Ozone and trace gases
- Precipitation systems studies
- Severe weather and mesoscale processes

Our work involves four primary activities or products: measurements, data sets, data analysis, and modeling, such as those listed in Table 1.

Table 1. Laboratory for Atmospheres Earth Science Activities

Measurements	**Data Sets**	**Data Analysis**	**Modeling**
Aircraft	DAO assimilated products	Aerosol cloud climate interaction	Atmospheric chemical
Balloon	Global precipitation	Aerosols	Clouds and mesoscale
Field campaigns	MODIS cloud and aerosol	Atmospheric Hydrologic cycle	Coupled climate/ocean
Ground	TOMS aerosol	Climate variability and climate change	Data assimilation
Space	TOMS surface UV	Clouds and precipitation	Data retrievals
	TOMS total ozone	Global temperature trends	General circulation
	TOVS Pathfinder	Ozone and trace gases	Radiative transfer
	TRMM Global Precipitation products	Radiation	Transport models
	TRMM validation Products	UV-B measurements	Weather and climate
		Validation studies	

The divisions among measurements, data sets, data analysis, and modeling are somewhat artificial, in that activities in one area often affect those in another. These activities are strongly interlinked and cut across science priorities and the organizational structure of the Laboratory. The grouping corresponds to the natural processes of carrying out scientific research: Ask the scientific question, identify the variable needed to answer it, conceive the best instrument to measure the variable, analyze the data, and ask the next question.